TABLE 11-2
Screening of Technologies for Groundwater and Leachate

Technology	Description	Effectiveness	Implementability	Relative Cost	Retained?	Comments
In Situ Biological Treatment						
Injection of Oxygen-Releasing Compound	A solution containing an oxygen-releasing compound is injected into saturated matrices to increase oxygen content and promote aerobic biodegradation.	◉	◉	◉	—	Effective to some extent for benzene, chlorobenzene, and 1,4-dichlorobenzene but not for PCE, TCE, or cis-1,2-DCE. Expensive relative to biosparging.
Biosparging	Air in injected into saturated matrices to increase oxygen content and promote aerobic biodegradation. Some contaminants also removed through volatilization. (Biosparging is a particular mode of air sparging that emphasizes aerobic biodegradation over volatilization.)	◉	●	●	Yes	Effective to some extent for benzene, chlorobenzene, and 1,4-dichlorobenzene but not for PCE, TCE, or cis-1,2-DCE. Requires management and/or treatment of vapors generated during sparging.
Enhanced Anaerobic Bioremediation	The rate of anaerobic bioremediation of organic contaminants by microbes is enhanced by adding a degradable substrate that releases hydrogen, which is used in reductive dechlorination of contaminants.	◉	◉	◉	—	Effective to some extent for all site COCs in groundwater. Potentially difficult to get good distribution of the degradable substrate in the aquifer and often results in increased concentrations of iron and manganese in the groundwater.
Monitored Natural Attenuation	Natural subsurface processes—such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials—are allowed to reduce contaminant concentrations to acceptable levels.	◉	●	●	Yes	Inexpensive relative to other technologies. Effective to some extent on all site COCs in groundwater. Easily implemented.
Phytoremediation	Phytoremediation is a set of processes that uses plants to remove, transfer, stabilize and destroy organic/inorganic contamination in ground water, surface water, and leachate.	○	○	◉	—	Not effective for deep groundwater.
In Situ Physical/Chemical Treatment						
Air Sparging	Air is injected into saturated matrices to remove contaminants primarily through volatilization.	◉	●	◉	Yes	Effective to some extent for all site COCs in groundwater. Requires treatment of vapors generated during sparging.
Bioslurping	Bioslurping combines the two remedial approaches of bioventing and vacuum-enhanced free-product recovery. Bioventing stimulates the aerobic bioremediation of hydrocarbon-contaminated soils. Vacuum-enhanced free-product recovery extracts LNAPLs from the capillary fringe and the water table.	○	○	◉	—	Not applicable to site conditions.
Chemical Oxidation	Oxidation chemically converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide.	◉	◉	○	—	Expensive relative to other technologies at the scale required.
Directional Wells (enhancement)	Drilling techniques are used to position wells horizontally, or at an angle, to reach contaminants not accessible by direct vertical drilling.	●	●	◉	—	Sites at Sauget Area 1 are open and suitable for direct vertical drilling.
Dual Phase Extraction	A high vacuum system is applied to simultaneously remove various combinations of contaminated ground water, separate-phase petroleum product, and hydrocarbon vapor from the subsurface.	◉	◉	○	—	Expensive relative to other effective technologies.

Notes:
COC = Chemical of concern. DNAPL = Dense non-aqueous phase liquid. GW = Groundwater. LNAPL = Light non-aqueous phase liquid. VOC = Volatile organic compound.

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Technology	Description	Effectiveness	Implementability	Relative Cost	Retained?	Comments
Thermal Treatment	Steam is forced into an aquifer through injection wells to vaporize volatile and semivolatile contaminants. Vaporized components rise to the unsaturated zone where they are removed by vacuum extraction and then treated.	●	●	○	—	Expensive relative to other effective technologies.
Hydrofracturing Enhancements	Injection of pressurized water through wells cracks low permeability and over-consolidated sediments. Cracks are filled with porous media that serve as substrates for bioremediation or to improve pumping efficiency.	○	○	○	—	Not applicable to site conditions.
In-Well Air Stripping	Air is injected into a double screened well, lifting the water in the well and forcing it out the upper screen. Simultaneously, additional water is drawn in the lower screen. Once in the well, some of the VOCs in the contaminated ground water are transferred from the dissolved phase to the vapor phase by air bubbles. The contaminated air rises in the well to the water surface where vapors are drawn off and treated by a soil vapor extraction system.	○	●	○	—	Not effective for SVOCs. Requires treatment of vapors.
Passive/Reactive Treatment Walls	These barriers allow the passage of water while causing the degradation or removal of contaminants.	◉	○	○	—	Potentially effective for all site COCs in groundwater but difficult to install and expensive due to depth and thickness of saturated zone.
Ex Situ Biological Treatment						
Bioreactors	Contaminants in extracted ground water are put into contact with microorganisms in attached or suspended growth biological reactors. In suspended systems, such as activated sludge, contaminated ground water is circulated in an aeration basin. In attached systems, such as rotating biological contractors and trickling filters, microorganisms are established on an inert support matrix.	○	●	○	—	Not effective for some SVOCs. Not effective when NAPL is present. Requires groundwater extraction.
Constructed Wetlands	The constructed wetlands-based treatment technology uses natural geochemical and biological processes inherent in an artificial wetland ecosystem to accumulate and remove metals, explosives, and other contaminants from influent waters. The process can use a filtration or degradation process.	○	○	○	—	Not applicable to site conditions.
Ex Situ Physical/Chemical Treatment						
Adsorption/ Absorption	In liquid adsorption, solutes concentrate at the surface of a sorbent, thereby reducing their concentration in the bulk liquid phase.	○	●	○	—	Not effective when NAPL is present. Requires groundwater extraction.
Advanced Oxidation Processes	Advanced Oxidation Processes including ultraviolet (UV) radiation, ozone, and/or hydrogen peroxide are used to destroy organic contaminants as water flows into a treatment tank. If ozone is used as the oxidizer, an ozone destruction unit is used to treat collected off gases from the treatment tank and downstream units where ozone gas may collect, or escape.	○	●	○	—	Not effective when NAPL is present. Requires groundwater extraction.

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Technology	Description	Effectiveness	Implementability	Relative Cost	Retained?	Comments
Air Stripping	Volatile organics are partitioned from extracted ground water by increasing the surface area of the contaminated water exposed to air. Aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.	◉	●	◉	Yes	Potentially useful technology for treatment of leachate and/or groundwater at Sauget Area 1.
Granulated Activated Carbon/Liquid Phase Carbon Adsorption	Ground water is pumped through a series of canisters or columns containing activated carbon to which dissolved organic contaminants adsorb. Periodic replacement or regeneration of saturated carbon is required.	◉	●	◉	Yes	Potentially useful technology for treatment of leachate and/or groundwater at Sauget Area 1.
Groundwater Pumping/Pump & Treat	Ground water pumping is a component of many pump-and-treat processes, which are some of the most commonly used ground water remediation technologies at contaminated sites.	●	●	○	Yes	Commonly used for plume containment and source mass reduction.
Ion Exchange	Ion exchange removes ions from the aqueous phase by exchange with counter ions on the exchange medium.	○	●	○	—	Not applicable to site conditions.
Precipitation/Coagulation/ Flocculation	This process transforms dissolved contaminants into an insoluble solid, facilitating the contaminant's subsequent removal from the liquid phase by sedimentation or filtration. The process usually uses pH adjustment, addition of a chemical precipitant, and flocculation.	◉	●	○	Yes	Potentially useful technology for removal of metals from recovered leachate.
Separation	Separation techniques concentrate contaminated waste water through physical and chemical means.	◉	●	●	Yes	DNAPL and water separation would be applicable to total fluids pumped from well BR-I at Site I.
Sprinkler Irrigation	The process involves the pressurized distribution of VOC-laden water through a standard sprinkler irrigation system.	○	○	●	—	Not applicable to site conditions.
Containment						
Physical Barriers	These subsurface barriers consist of vertically excavated trenches filled with slurry. The slurry, usually a mixture of bentonite and water, hydraulically shores the trench to prevent collapse and retards ground water flow.	●	○	○	—	Effective for all COCs but difficult to install and expensive due to depth and thickness of saturated zone.
Deep Well Injection	Deep well injection is a liquid waste disposal technology. This alternative uses injection wells to place treated or untreated liquid waste into geologic formations that have no potential to allow migration of contaminants into potential potable water aquifers.	○	◉	◉	—	Not applicable to site conditions.
Groundwater Capture						
Interceptor trench	An interceptor trench consists of a perforated pipe laid in a trench and covered with a high permeability material, typically gravel. The trench intercepts groundwater flow and channels the captured groundwater to sumps, where it is pumped to the surface.	○	○	○	—	Not applicable to site conditions.
Conventional extraction wells	Traditional extraction wells are vertically-drilled wells that pump groundwater from a screened interval.	●	●	◉	Yes	Possible component of any alternative that requires groundwater extraction.

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Technology	Description	Effectiveness	Implementability	Relative Cost	Retained?	Comments
Conventional injection wells	Traditional extraction wells are vertically-drilled wells that inject water into a screened interval. Used to channel groundwater into desired flow paths, and as a method of disposal of treated groundwater.	●	●	◎	__	Not applicable to site conditions.
Wellpoint system	System of many vertical wells discharging to a common header at the surface. Useful for low permeability soils where many closely-spaced wells are required.	●	●	◎	__	Not applicable to site conditions.
Air Emissions/Gas Treatment						
Biofiltration	Vapor-phase organic contaminants are pumped through a soil bed and sorb to the soil surface where they are degraded by microorganisms in the soil.	○	●	◎	__	Not effective for all site COCs.
High Energy Destruction	The high energy destruction process uses high-voltage electricity to destroy VOCs at room temperature.	●	●	○	__	Expensive relative to other effective technologies.
Membrane Separation	This organic vapor/air separation technology involves the preferential transport of organic vapors through a nonporous gas separation membrane (a diffusion process analogous to putting hot oil on a piece of waxed paper).	◎	●	○	__	Expensive relative to other effective technologies.
Oxidation	Organic contaminants are destroyed in a high temperature 1,000°C (1,832 °F) combustor. Trace organics in contaminated air streams are destroyed at lower temperatures, 450 °C (842 °F), than conventional combustion by passing the mixture through a catalyst.	●	●	○	Yes	Possible component of a vapor treatment system for air sparging or biosparging.
Scrubbers	Scrubbers remove air pollutants by inertial or diffusional impaction, reaction with a sorbent or reagent slurry, or absorption into a liquid. Scrubbers are used to remove water-soluble acid, base, and organic contaminants and to control particulate matter.	◎	◎	○	__	Expensive relative to other effective technologies.
Vapor Phase Carbon Adsorption	Off-gases are pumped through a series of canisters or vessels containing activated carbon to which organic contaminants adsorb. Periodic replacement or regeneration of saturated carbon is required.	●	●	◎	Yes	Possible component of a vapor treatment system for air sparging or biosparging.

Symbol key:

● = Higher than average effectiveness and implementability, lower than average cost.

◎ = Average effectiveness and implementability, average cost.

○ = Lower than average effectiveness and implementability, higher than average cost.

Notes:
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